THURSDAY, JANUARY 29, 1885

THE STABILITY OF SHIPS[1]

A Treatise on the Stability of Ships. By Sir E. J. Reed, K.C.B., F.R.S., M.P. (London: C. Griffin and Co., 1885.)

II.

IN simplifying the mode of presentation of the scientific principles which govern the stability of ships, Sir E. J. Reed touches upon a very important point—the defects of nomenclature. The technical nomenclature of naval architecture has gradually been formed in an unsystematic and often heedless and unintelligent manner; and it contains many inconsistencies and inaccuracies. Attention has previously been called by ourselves and others to the subject. Sir Edward Reed refers to the confusion that is sometimes caused by giving the name "metacentre" to points upon two curves which are quite distinct from each other. One of these curves indicates the variation in the height of the metacentre with draught of water when the ship is upright; and the other is that formed by the intersections of consecutive normals to the curve of buoyancy as a ship becomes inclined from the upright. These two curves are entirely different in character, and have only one point in common—viz. the *metacentre* for the upright position corresponding to the draught of water for which the curve of intersections of consecutive normals is constructed. The latter curve is, of course, the evolute of the curve of buoyancy. Sir Edward Reed proposes to call the intersections of consecutive normals to the curve of buoyancy at all angles of inclination from the upright "pro-metacentres," and to restrict the use of the term "metacentre" to indefinitely small inclinations from positions of equilibrium.

The points described as "pro-metacentres" are centres of curvature of the curve of buoyancy. They are but of little importance to practical naval architects, and are probably never regarded by them. To persons who may be pursuing investigations in which such points require to be dealt with, such a term as "pro-metacentre" may be of use. Sir Edward Reed truly says that the points in question "are not 'meta-centres,' except in a very strained, misleading, and wholly exceptional sense." They do not enter into any of the considerations by which the stability of a ship is judged of or calculated; and their positions are not determined, nor even known, in practice.

If Fig. 2 represents the section of a ship, $B B_3$ the curve of centres of buoyancy, and $M M_3$ the curve of intersections of consecutive normals to $B B_3$, or the evolute of $B B_3$, then the points M_1, M_2, and M_3 will be the "pro-metacentres" corresponding to those angles of inclination at which $M_1 B_1$, $M_2 B_2$, and $M_3 B_3$ are respectively vertical. M is the point corresponding to the position of equilibrium when the vessel is upright, and is the metacentre proper. Such points as M_1, M_2, and M_3 have sometimes been miscalled metacentres, and the curve $M M_3$ the metacentric evolute. Sir E. J. Reed proposes to call these points "pro-metacentres," and the curve $M M_3$ the "curve of pro-metacentres." M_1, M_2, and M_3 are centres of curvature of $B B_3$ at the points B_1, B_2, and B_3; and the curve $M M_3$ is the evolute of $B B_3$.

Sir Edward reminds us that the points where the lines $M_1 B_1$, $M_2 B_2$, and $M_3 B_3$ intersect the vertical axis of equilibrium through B, have sometimes, in this country, been called "shifting metacentres"; and he considers that although this term has a "measure of justification, its use is not very desirable, and is, indeed, likely, unless great care is taken, to introduce misconceptions into the subject." It is true that the term "shifting metacentre" was suggested for application to these points, even by so eminent an authority as the late Prof. Macquorne Rankine; but it has failed of its purpose, and passed so completely into oblivion that if Sir Edward had not referred to the circumstance few of his readers would have remembered it. There is little probability of the term "shifting metacentre" now coming into use.

The most natural mode of treating these points is doubtless to class them all in the category of "metacentres," without any qualifying adjective of a general character, such as "shifting." In France the term metacentre includes the point M—which we regard as being the metacentre proper—and Prof. Rankine's shifting metacentres. It is natural to regard the intersection of $M_2 B_2$ with the vertical axis of equilibrium as the metacentre for the particular angle of inclination to which $M_2 B_2$ relates. This is quite consistent with Bouguer's original definition of the metacentre, viz. "la terme que la hauteur du centre de gravité G, ne doit pas passer, et ne doit pas même attendre." This point constitutes the limit above which the centre of gravity cannot be raised without causing the ship to move farther away from the upright, whether the angle of inclination be great or small. It is convenient, and need not be ambiguous, to call these points metacentres for the particular angles of heel to which they relate. Thus the intersection of $M_1 B_1$ with the vertical axis of equilibrium through B is the metacentre at 10° of inclination, if 10° be the angle at which $M_1 B_1$ is vertical; and the same for any other angle.

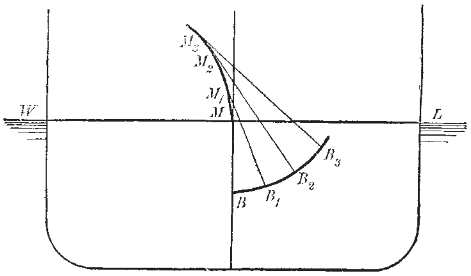

FIG. 2.

These points are really of importance to the naval designer, as the distance from such a point to the centre of gravity at any angle of inclination, say 30°, is equal to the length of the ship's righting lever divided by the sine of the angle of inclination. If this distance be zero the righting lever vanishes, and there will be no resistance to further inclination. If the metacentre at 30° fall below the centre of gravity the ship will tend to incline still farther; but if it be above the centre of gravity she will tend to return towards the upright position. Sir Edward Reed objects to calling these points metacentres when the angles of inclination are large, because they really have "nothing to do with limiting the height to which the centre of gravity can be raised without disturbing the upright position of the ship." We do not see that any such property is implied by calling the metacentre for a certain angle of inclination the metacentre belonging to that inclination, which is what the French do. There is no doubt that the French method is a natural and useful one. It is also one which has been adopted by many in this country, and is likely to become general. M. E. Bertin, of Brest, says that the nomenclature adopted throughout France for many years past has been such as to leave no room for difficulties of interpretation. But while Sir Edward Reed objects to the French practice in this respect, as well as to Prof. Rankine's "shifting metacentre," he does not propose a substitute for either.

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[1] Continued from p. 240.

There are other matters connected with the nomenclature of this branch of science which might have been profitably dealt with by the author. Take, for instance, the common use of the term stability. The stability of a floating body is determined by the forces which resist its angular motion from a position of equilibrium, and by the angular distance over which such forces operate. What is called the curve of stability is a curve of which the abscissæ denote angles of inclination and the ordinates are proportional to the righting moments. This may quite properly be called a curve of stability, as it gives a complete graphic representation of the various elements of stability. But the righting moment possessed by a ship at a given angle of inclination is frequently called the statical stability at that angle: while, by a still stranger misuse of scientific language, the work required to be done to incline her from the upright position of equilibrium to the angle in question is called the *dynamical stability* at that angle. Stability exists only at positions of equilibrium; and it is absurd to speak of foot-tons of stability at a given angle of inclination from one of those positions, as is frequently done. Such mistakes can only be due to the confusion which exists in many minds between stability and righting moment. Prof. Osborne Reynolds called attention to the point at the meeting of the British Association in 1883. Whether any intelligible meaning is supposed to be conveyed by the words "dynamical stability developed during inclination," we do not know; at any rate, we cannot discover what it is. Sir E. J. Reed has done good service by approaching the question of mistaken and ambiguous terms in naval architecture. We are only sorry that he has not dealt more thoroughly with it.

Sir Edward gives numerous illustrations of curves of metacentres, and curves of stability, for various types of ships; so that the effect upon them of variation in the proportions and form, and also in the loading, of various types of vessels, may be studied. These curves are given for broadside armour-clads, low freeboard turret-ships, and armoured cruisers of our own and other navies; and for passenger and cargo steamers. The latter include examples which show the character of the stability that many vessels of the "well-deck" type possess.

The subject of longitudinal stability is fully dealt with; and the effect of admitting water into a watertight compartment is discussed. The method of determining the height of the longitudinal metacentre is explained; and also the moment required to alter the trim of a given ship by a fixed amount. The changes of trim produced by putting weights into or taking weights out of a ship are clearly described. The stability of a vessel fitted with watertight compartments, and having water admitted into one or more of them by collision, or otherwise, is investigated with great fulness of detail. The following distinct conditions are considered: (1) When a closed compartment is completely filled with water; (2) when a closed compartment is partially filled with water; and (3) when a compartment contains water in free communication with the sea, and in which the water maintains the same level as the sea for all inclinations. In dealing with this subject Sir E. J. Reed substantially follows the lines laid down by Mr. F. K. Barnes, of the Admiralty, in papers read before the Institution of Naval Architects in 1864 and 1867. Mr. Barnes has very ably and lucidly explained the effect upon the metacentric height which is produced by laying a central compartment in a ship open to the sea and filling it with water; and also the effect produced by thus filling compartments which are formed by longitudinal bulkheads. The results are given, in both cases, for compartments of various sizes and proportions.

Sir Edward devotes a chapter to the consideration of "dynamical stability," and gives the views that have been put forward respecting it by the late Canon Moseley and by MM. Moreau, Bertin, Risbec, and Duhil de Benazé. He also quotes an interesting and ingenious investigation by M. Guyou, of the French Navy, which includes a somewhat novel treatment of the problem of dynamical stability. We have already objected to the use of the phrase "dynamical stability." The author explains that what is called the dynamical stability at a given angle of inclination is the work done by an inclining force in heeling the ship from the upright position of equilibrium through that angle. The "total work is the dynamical stability." Dynamical stability is consequently spoken of as being "developed during the inclination of the ship from one angle to another." Resistance is overcome, and work is done, in inclining a ship from one angle to another against the action of righting forces; but we cannot understand why such work should be called "dynamical stability."

The work done in inclining a ship from one angle to another is, of course, the resistance to such inclination multiplied by the distance through which the resistance is overcome. This resistance is constituted by the weight of the ship acting vertically downwards through its centre of gravity, and an equal and opposite force acting vertically upwards through the centre of gravity of the displaced water. Therefore the total work performed during an inclination is the weight of the ship multiplied by the vertical increase of distance between the centre of gravity of the ship and the centre of gravity of the displaced water.

This treatise contains an instructive chapter upon M. Amsler-Laffon's mechanical integrator. The ordinary pivot-planimeter, which is a more common and very valuable instrument, is not referred to; but the integrator which combines appliances for computing areas, moments, and moments of inertia of plane curves is described. This instrument has lately been introduced into ship-drawing offices, and is highly appreciated for the saving of time and labour which can be effected by its use, and for its comparative freedom from error. Complicated calculations can be made with this ingenious piece of mechanism by less highly-skilled draughtsmen than are required for performing the ordinary arithmetical calculations. This is a very important matter in mercantile shipyards, where the supply of scientifically-trained draughtsmen is not great. In referring to this point Sir E. J. Reed says that "in most private shipbuilding establishments these lads (drawing-office apprentices) are now required to pass an examination similar to that which candidates undergo for apprenticeship in Her Majesty's dockyards." We do not understand that this is so. It may be the case with one or two firms, but the system is a very exceptional one. Sir E. J. Reed gives a mathematical investigation of the properties of the integrator, and explains how to take off the readings for areas, moments, and moments of inertia. We notice an omission in connection with the figures given for the various constants that require to be applied as multipliers to these readings, for the purpose of converting them into actual units of measurement. The particular instrument to which the constants apply is not fully stated. The constant for areas, given as 15, and that for the area term in the expression for moment of inertia, given as 240, relate to instruments formerly supplied by M. Amsler, which had a different diameter of area wheel from those now made. We believe that the circumference of the area wheel is now 2·5 inches; so that the two constants which depend upon the size of the area wheel would, in that case, be 20 and 320, instead of 15 and 240.

The final chapters of the treatise deal with general questions relating to the rolling of ships at sea, and the effect of wind-pressure upon stability when ships are sailing among waves. The method of obtaining by experiment the vertical position of a ship's centre of gravity, and the precautions which have to be adopted in order to ensure fairly accurate results, are described.

The few omissions and defects we have pointed out are but of minor importance, and do not appreciably affect the general value of this very important treatise. It is not only the largest that has ever appeared in this country, but also the most intelligible, instructive, and complete exposition of the principles of stability. It forms a most valuable addition to the science of naval architecture, and one that has long been needed. Till now we have been unable to refer persons desirous of studying the various problems connected with the stability of ships to any work in which they would find the subject treated in a clear and comprehensive manner. Sir E. J. Reed has supplied a want that has long existed. We strongly recommend his book to all who are interested in the subject, and particularly to those whose connection with ships requires them to know upon what conditions stability depends, and how it is affected by all the various circumstances of construction and loading which may arise. Such a treatise should be especially welcome to students.

OUR BOOK SHELF

In the Lena Delta; a Narrative of the Search for Lieut.-Commander De Long and his Companions, followed by an Account of the Greely Relief Expedition and a Proposed Method of Reaching the North Pole. By G. W. Melville; Edited by G. Melville Philips. (London: Longmans and Co., 1885.)

THE sad story of the *Jeannette* Expedition has already been very fully told in the two volumes of journals left by Capt. De Long. Still, we do not object to this more detailed narrative of the experiences in the Lena Delta of those who managed to reach it, by the one most qualified to speak of them. It was by the strenuous exertions of Engineer Melville that the bodies of Capt. De Long and his companions were discovered, and that the few survivors were rescued. Concerning the physical and biological conditions of the great swamp formed about the mouths of the Lena, Mr. Melville does not tell us much more than we knew already; but his continual journeys to and from between the delta and such towns as Yakutsk, Tiumen, and others in this part of Siberia necessarily furnish us with many details of interest. As a story of remarkable adventures the book is certainly interesting. Mr. Melville's arctic enthusiasm was not in the least damped by the *Jeannette* misfortunes. Not only does he describe in the present volume his experiences as a member of the Greely Relief Expedition, but he means evidently to attempt to reach the Pole, if for no other reason but that it "may prevent other fools from going there." Mr. Melville's plan takes for granted that Franz Josef Land reaches to 85° N., which is probable enough; and he would therefore propose to utilise this as a basis of operations; around the Pole he supposes that a partial "vacuum" exists, and that partly as a consequence the ice-cap there is immovable, held in its place by the islands which he believes surround it. As to getting back when the Pole is reached, Mr. Melville believes that this could easily be effected either by Nova Zembla or Spitzbergen. Of course, the retreat would be secured by the establishment of carefully-selected depots. "Finally, I propose to prove this theory of reaching the North Pole by *going there myself.*" Every one will wish him God speed; and there can be no doubt that the best arctic authorities are agreed that the next expedition should seriously try the Franz Josef Land route.

Stanford's Compendium of Geography and Travel—Europe. By F. W. Rudler, F.G.S., and G. W. Chisholm, B.Sc. Edited by Sir Andrew C. Ramsay, LL.D., F.R.S. With Ethnological Appendix by A. H. Keane, M.A.I. (London: Stanford, 1885.)

THIS many-authored and much-edited volume is the last of the series of Stanford's well-known "Compendium," the first volume of which was issued some six years ago. That first volume dealt with Africa, and was edited, it may be remembered, by Mr. Keith Johnston, who shortly after publication lost his life attempting to explore the continent which he had so well described. There have been subsequent editions of that volume edited by Mr. E. G. Ravenstein. The succeeding volumes were South America, by Mr. H. W. Bates; Australasia, by Mr. A. R. Wallace; Asia, by Prof. Keane and Sir Richard Temple; and North America, by Drs. Hayden and Selwyn. It will thus be seen that Mr. Stanford has been fortunate in his choice of editors for the several volumes. The Compendium professes to be based on Hellwald's German work, but it may throughout be regarded as virtually original. The various editors have put so much of their own into their several volumes, and given to the whole an orientation so essentially English, that it would be difficult to tell which is Hellwald and which the "editors." In the present volume the editors and authors (or one of them, for the title-page is awkward) have wisely